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The partial reinforcement effect sustained through blocks of continuous reinforcement in classical eyelid conditioning.

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THE PARTIAL REINFORCEMENT EFFECT SUSTAINED THROUGH BLOCKS OF CONTINUOUS REINFORCEMENT IN CLASSICAL EYELID CONDITIONING

PERRY

The Partial Reinforcement Effect Sustained Through Blocks of Continuous Reinforcement in Classical Eyelid Conditioning

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The purpose of this study was to investigate the effect of a shift from partial to continuous reinforcement in acquisition upon resistence to extinction in classical eyelid conditioning.

In 1939 Humphreys demonstrated that in eyelid conditioning with human Ss resistence to extinction following partial reinforcement is superior to that following continuous reinforcement and proposed a discrimination hypothesis to account for this finding. According to the discrimination hypothesis, resistence to extinction is inversely related to the degree of discriminability of the shift from the acquisition to the extinction situation. An essential feature of this theory is the notion that the S's performance in extinction depends upon his anticipation of reinforcement or nonreinforcement. The contrast between continuous reinforcement in acquisition and no reinforcement in extinction is presumably optimal for a change in expectation and produces a sudden decrement in responding during extinction whereas the contrast between partial reinforcement in acquisition and no reinforcement in extinction is not optimal. The S learns to expect that periods of nonreinforcement will be followed by periods of reinforcement, and, therefore, he continues to respond for longer periods of time during extinction than he would if he had been trained under continuous reinforcement. The partial reinforcement effect (PRE) has since been obtained in several eyelid conditioning experiments (Hake and Grant, 1951; Grant and Hake, 1951; Grant and Schipper, 1952; Grant, Schipper, and Ross, 1952; Hartman and Grant, 1960; Froseth and Grant, 1961).

Grant, Riopelle, and Hake (1950), using magnitude as a measure

of responding (Humphreys, 1943), found extinction following single and double alternation of reinforced and nonreinforced trials to be similar to extinction following 100% reinforcement, whereas extinction following random intermittent reinforcement was described by a different function. Presumably, the single and double alternation groups as well as the 100% reinforcement group were able to verbalize the pattern of reinforcement whereas this was not possible for the partial reinforcement group. According to the discrimination hypothesis, the shift from acquisition to extinction would be more pronounced for the groups which were able to verbalize the reinforcement pattern.

Moore and Gormezano (1963), using omitted- and delayed-UCS groups in acquisition (McAllister, 1953; Ross, 1959), found that the delayed-UCS group extinguished more rapidly under 0% reinforcement than did the omitted-UCS group. These results can be interpreted as supporting the discrimination hypothesis. The shift from acquisition to extinction was more pronounced for the delayed-UCS group since the CS was always followed by the UCS in acquisition, whereas in extinction the CS was never followed by the UCS. On the other hand, the omitted-UCS group received both UCS and non-UCS trials during acquisition, and, consequently, the discrimination between acquisition and extinction was more difficult to make.

A cognitive approach has recently been taken by Spence in interpreting rate of extinction as a function of the change in conditions from acquisition to extinction. Spence (1963) found that resistence to extinction for Ss trained under continuous reinforce-

ment and extinguished with delayed-UCS was higher than for Ss extinguished under omitted-UCS conditions. Further, Ss who were given a probability-learning task simultaneously with conditioning and were extinguished with a delayed-UCS were more resistent to extinction than either the omitted-UCS group or the delayed-UCS group which had not been given an additional learning task. The additional learning task presumably served to minimize the awareness of the change in conditions from acquisition to extinction. Spence's version of the discrimination hypothesis, which is almost identical with Humphreys' original statement, is presented in Spence, Rutledge, and Talbott (1963).

According to the discrimination hypothesis, a block of continuously reinforced trials interpolated between a series of partially reinforced trials and extinction should increase the discriminability between the training and extinction situations and should, therefore, lead to a larger decrement in responding than would be observed if the block of continuous trials were not interpolated immediately prior to extinction. A number of studies have tested this prediction. Quartermain, Vaughan, and Mangan (1961) trained rats under partial and partial-continuous reinforcement schedules and found that the partial-continuous group was more resistent to extinction than the partial group. In order to test the prediction that a shift in reinforcement schedule may have been the crucial variable, Quartermain and Vaughan (1961) trained rats under 10-100%, 10-25%, and 10-10% reinforcement schedules and found no differences among groups in extinction. Clearly these results do not support the discrimination hypothesis. Jenkins (1962) found that with

pigeons in a free-responding situation, abruptness of the change in reinforcement schedule from training to extinction did not affect resistence to extinction. Instead, the PRE persisted in spite of a period continuous reinforcement immediately preceding extinction. Theois (1962) found essentially the same results with rats in a runway situation. In this experiment, two groups received different amounts of continuous reinforcement throughout acquisition, two groups received 50% reinforcement followed by different amounts of continuous reinforcement, and a fifth group received 50% reinforcement throughout acquisition. It was found that in spite of the continuous reinforcement immediately before extinction, rats trained under partial reinforcement were all more resistent to extinction than those trained only under continuous reinforcement. In a noncontingent two-choice probability-learning task the effects of shifts in reinforcement schedule upon resistence to extinction were investigated by Capaldi and Capaldi (1963). Again it was found that any group having received partial reinforcement <u>at any time</u> was more resistent to extinction than a group which never received partial reinforcement. Taken together these experiments indicate that the abruptness of the transition in reinforcement schedule from acquisition to extinction cannot entirely explain the PRE, and, therefore, the adequacy of the discrimination hypothesis must be questioned.

Since the evidence against the discrimination hypothesis comes from studies of instrumental conditioning using an interpolated 100% reinforcement design, it was the purpose of the present study

to determine whether the discrimination hypothesis can at least be applied to human classical conditioning or if it must be modified or abandoned in favor of a theory of partial reinforcement which emphasizes possible long-lasting effects of nonreinforcement (Lawrence and Festinger, 1962).

Method

Subjects and design. A total of 81 students from introductory and summer psychology classes and volunteers at the University of Massachusetts served as Ss. Group 50-50 received 50 per cent partial reinforcement throughout all 80 acquisition trials. Group 50-100 received 50 per cent partial reinforcement during the first 40 acquisition trials and was shifted to 100 per cent reinforcement for the remaining 40 trials. Group 100-100 received 100 per cent reinforcement for all 80 acquisition trials. Three Ss from each group were eliminated for failure to give at least three conditioned responses in the last block of 10 acquisition trials. Of the remaining 72 Ss, 12 were randomly assigned to each of six cells in a 3 X 2 factorial design where schedule of reinforcement and sex represented the dimensions of the experiment. In addition to 80 acquisition trials, all groups received 20 extinction trials with no UCS.

Apparatus and method of recording. The S was seated in a dental chair in a 6' X 7'5" well-illuminated room. The conditioned stimulus (CS) consisted of an 800 cps tone of 70 db SPL provided by a Hewlett-Packard audio-oscillator. The unconditioned stimulus (UCS) was an air puff of 1.0 lb/sq in pressure delivered to the right eye by means of a nozzle attached to the headset worn by S. The duration of the stimuli and the interval between them was controlled by Hunter interval timers, and the intertrial interval was automatically controlled by a Grayson-Stadler interval programmer. The apparatus was situated in a room adjoining the experimental room; any noise

resulting from the equipment was masked by a 66 db SPL noise provided by a fan located in the experimental room.

The S's eyelid movements were measured by a combination of mechanical and electrical means. A light-weight aluminum lever was attached to S's eyelid with adhesive tape. This was connected by a piece of light-weight, stiff wire to the rotating arm of a microtorque potentiometer located on the headset S wore. A tension spring attached to this arm maintained the wire in a taut position so that up and down movements of the eyelid were recorded but restriction of eyelid movement was minimal. The movement of the eyelid and subsequent movements of the potentiometer arm produced a signal which was amplified by a Hunter eyeblink amplifier so as to operate an oscillographic pen motor. During a trial, the recording paper moved through a Brush recorder at the rate of 120 mm/sec. An additional recorder ran continuously at a rate of 5 mm/sec to provide a measure of intertrial responding.

Conditioning procedure. A set of "neutral" instructions (Gormezano and Moore, 1962) was administered to S immediately before the first trial. On reinforced trials, the CS was presented for 550 msec and terminated together with a 50 msec UCS. On nonreinforced trials, the CS was presented without the UCS for 550 msec. A 50 per cent reinforcement schedule was employed for partially reinforced groups and was restricted such that no more than four nonreinforced trials occurred consecutively and such that within each block of 10 trials there were an equal number of reinforced and nonreinforced trials. The intertrial intervals were 15.0, 22.5, and 30.0 sec,

randomly distributed.

Response measures. The criterion for a conditioned response (CR) was any deflection of the recording pen of at least one mm from the baseline and occurring in the latency range of 150-500 msec after the onset of the CS.

Intertrial responses were measured in order to adjust conditioning scores for S's operant level of responding. The criterion for an intertrial response was any excursion and return of the recording pen of at least one mm. The blink rate for each intertrial interval was obtained by adding up the number of blinks in the interval and dividing by the number of successive 500-msec segments within that interval. Under the assumption that each 500-msec segment can contain no more than one response, this procedure permitted the percentage intertrial blink rate to be placed on the same scale of measurement as percentage CRs.

Results

Figure 1 presents the percentage CRs for the three groups over blocks of 10 acquisition trials and subsequent blocks of 5 extinction trials. The first point on each curve refers to the percentage CRs on trial 1. As may be seen, group 100-100 conditioned at a faster rate and reached a higher asymptote than did groups 50-50 and 50-100; the final level of conditioning for group 100-100 was 79 per cent. During the first half of acquisition, group 50-50 conditioned at a faster rate and reached the 54 per cent level by trial-block 4, while group 50-100 conditioned more slowly and reached only the 40 per cent level at this point. However, during the last half of acquisition group 50-100, upon being shifted to continuous reinforcement, reached the 61 per cent level within 10 trials and a final level of 64 per cent, an increase of only 10 per cent over the last 40 trials.

The level of extinction responding was highest for group 50-50 and lowest for group 100-100. Group 50-100 extinguished at a level approximately halfway between groups 50-50 and 100-100. The rate of extinction was about the same for all groups. The sharpest drop in responding occurred during the first 10 trials of extinction and was followed by a slower decrease for the remaining 10 trials.

Extinction. For statistical analyses an arcsine transformation was applied to the following data: (a) percentage CRs for all 80 acquisition trials (b) percentage CRs for the last 40 acquisition trials (c) percentage CRs in extinction (d) percentage intertrial

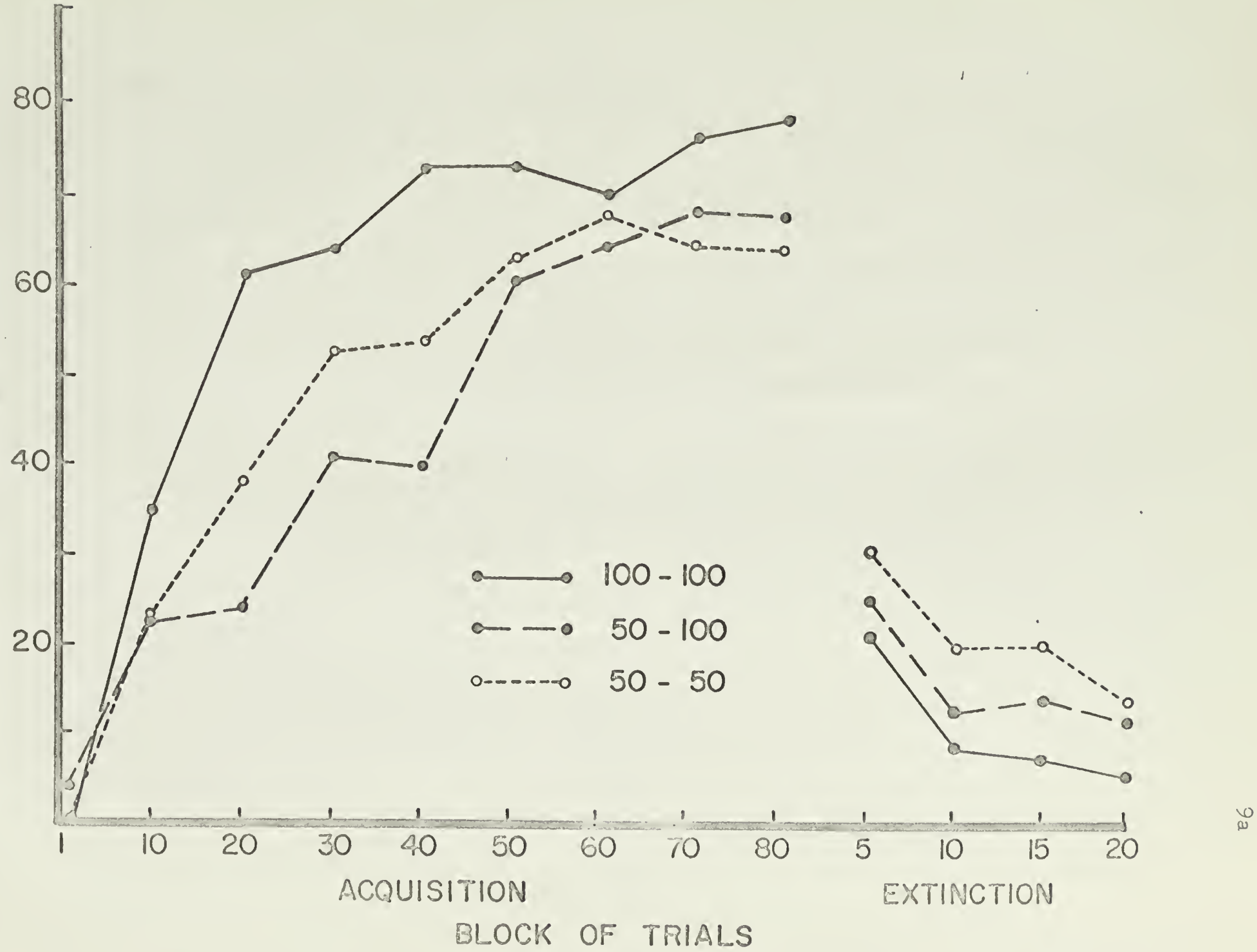

Fig. 1 Mean percentage CRs as a function of 10-trial blocks in acquisition and 5-trial blocks in extinction with schedule of reinforcement as the parameter.

responding during acquisition and (e) percentage intertrial responding during extinction. These measures will subsequently be referred to as (a) acquisition scores (b) asymptotic acquisition scores (c) extinction scores (d) blink rate in acquisition and (e) blink rate in extinction, respectively.

An analysis of variance performed on extinction scores yielded a significant main effect due to schedule of reinforcement in acquisition ($F(2, 66) = 3.91$, $p < .05$). When extinction scores were adjusted for acquisition scores by an analysis of covariance, schedule of reinforcement was highly significant ($F(2, 65) = 11.37$, $p < .001$). When extinction scores were adjusted for both acquisition scores and blink rate during extinction, schedule of reinforcement was again highly significant ($F(2, 63) = 12.97$, $p < .001$).

Since the asymptotic acquisition scores might be considered the more appropriate covariate adjustment in extinction, an analysis of covariance using this measure and blink rate in extinction as the covariates was performed. A significant main effect due to schedule of reinforcement ($F(2, 63) = 11.26$, $p < .001$) was obtained.

Individual comparisons were made between the adjusted means of the extinction scores of groups 50-50 vs. 50-100 and groups 50-100 vs. 100-100. Using acquisition scores and blink rate in extinction as the covariates, the adjusted means were 42.19, 37.35, and 20.04 for groups 50-50, 50-100, and 100-100, respectfully. The difference between groups 50-50 and 50-100 was

not significant while groups 50-100 and 100-100 differed significantly from each other (F (1, 63) = 15.84, $p < .001$). Using the asymptotic acquisition scores and blink rate in extinction as the covariates, the adjusted means were 37.95, 34.95, and 26.99 for groups 50-50, 50-100, and 100-100 respectively. Here group 50-100 did not differ significantly from either groups 50-50 or 100-100 but group 50-50 differed significantly from group 100-100 (F (1, 65) = 7.69, $p < .01$).

Intertrial blink rate. Intertrial blink rate in acquisition showed no differences among groups (F (2, 65) = .09) and, other than a slight decrease early in training, the blink rate remained essentially constant for all groups at about the 20 per cent level throughout acquisition. Intertrial blink rate in extinction showed no differences among groups (F (2, 65) = .38) but a significant difference due to sex (F (1, 65) = 7.01, $p < .05$) with males responding more between trials than females. The average blink rate remained constant at about the 15 per cent level for all groups throughout extinction. With respect to the two analyses of covariance performed on the extinction data, a comparison of the F ratios suggests that either the increased precision or the statistical control obtained by using intertrial blink rate as a covariate was small compared with the precision and control obtained by using acquisition scores as a covariate. The average intercell correlation between extinction scores and blink rate in extinction was .28.

Discussion

Extinction. The discrimination hypothesis predicted that the group receiving partial reinforcement prior to extinction (50-50) would respond at a significantly higher level during extinction than would the two groups receiving continuous reinforcement prior to extinction (50-100 and 100-100). As predicted, group 50-50 responded at a significantly higher level during extinction than did group 100-100. However, group 50-100 extinguished at a level approximately halfway between groups 50-50 and 100-100. When extinction scores were adjusted for either the total acquisition scores or for the asymptotic acquisition scores, the adjusted means for group 50-100 were closer to those of group 50-50 than to those of group 100-100.

It would appear that the version of the discrimination hypothesis stated in the introduction is not sufficient to explain the extinction performance of group 50-100 in this experiment. However, if one assumes that resistence to extinction depends not only on S's awareness of the change in reinforcement schedule from acquisition to extinction but on his interpretation of the change in reinforcement, then an expanded form of the discrimination hypothesis might account for the results. The Ss in group 50-100 may interpret the onset of extinction as a reinstatement of partial reinforcement rather than as the start of extinction, and the extent to which such an interpretation is made should increase the level of responding of these Ss relative to those in group 100-100. The Ss in the latter group, having no previous experience with

cement, could not be expected to interpret the introduction of a partial reinforcement schedule.

: blink rate. Intertrial blink rate was found to constant over trials within both acquisition and is finding agrees with observations of Mattson and However, unlike the Mattson and Moore study, blink ree groups in the present experiment decreased diately after the shift from acquisition to extinc- crease can be explained by at least two hypotheses literature on eyelid conditioning. If blink rate is D, the decrease of 5 per cent might be attributed n D as a result of the absence of the UCS in extinc- 1958). Another explanation might be expressed in alization of inhibition of the eyelid response

If the on-trial response is being inhibited during en this inhibition might generalize to intertrial , hence, cause a decrement in responding. This the more unlikely of the two because if generali- on-trial and intertrial stimuli was operating in t, then, instead of remaining constant over trials, nking should have increased together with the rves and decreased with the extinction curves.

Summary

Two groups of 24 Ss received 80 eyelid conditioning trials with a schedule of reinforcement in acquisition of either 50%-random (group 50-50) or 100% (group 100-100). A third group of 24 Ss (group 50-100) was shifted from a 50%-random schedule to 100% on trial number 40. All three groups received 20 extinction trials. According to Humphreys' discrimination hypothesis, Ss trained under 50-100%, like Ss trained under 100% reinforcement, should discriminate the change in reinforcement schedule between acquisition and extinction more easily than Ss trained under 50% reinforcement and should, therefore, be significantly less resistent to extinction than the latter group.

The mean extinction scores of the three groups, adjusted by analysis of covariance for either (a) acquisition scores and intertrial responding during extinction or (b) asymptotic acquisition scores and intertrial responding during extinction, indicated that the extinction performance of group 50-100 was closer to that of group 50-50 than to that of group 100-100. A modified version of the discrimination hypothesis was proposed to account for the result.

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Appendix A

Instructions

Please listen carefully to the following instructions. Remain seated comfortably and keep looking in front of you. Do not touch anything on your head at any time during the experiment.

You will hear and feel a series of stimuli during the experimental session. Be careful not to control voluntarily your natural reactions to the stimuli. Do not try to figure out the experiment. Keep as detached an attitude as possible and simply let your reactions take care of themselves.

You can communicate with me at any time by speaking in a normal voice. Are these instructions perfectly clear to you?

Appendix B

F-ratios from Analyses of Variance and Covariance

of Arcsine Percentage Conditioned

Responses in Acquisition

		Anova		Anocova
SV	df	Based on 80 Acquisition Trials	Based on Last 40 Acquisition Trials	Based on 80 Acquisition Trials and Adjusted for Acquisition Blink Rate
Reinforcement Schedule (R)	2	4.19*	1.06	4.02*
Sex (S)	1	3.79	4.84*	5.57*
R X S	2	.20	.26	.62
Error (MS)	66	(190.41)	(260.37)	$(184.64)_a$

* p .05

a-One df was subtracted from Error for the covariate and 1 df for estimation of a missing data point from the blink rate scores.

Appendix C

F-ratios from Analyses of Variance and Covariance

of Arcsine Percentage Conditioned

Responses in Extinction

SV	df	Anova	Anocova		
		No Covariate Adjustment	Adjusted for Acquisition Scores and Blink Rate in Extinction	Adjusted for Acquisition Scores	Adjusted for Asymptotic Acquisition Scores and Blink Rate in Extinction
Reinforcement Schedule (R)	2	3.91*	12.97**	11.37**	11.26**
Sex (S)	1	.02	.08	1.75	2.96
R X S	2	.71	1.29	1.94	2.28
Error (MS)	66	(408.16)	$(226.89)_a$	$(252.33)_b$	$(226.89)_a$

* p .05
** p .001

a-One df was subtracted from Error for each of the two covariates and 1 df for estimation of a missing data point from the blink rate scores.

b-One df was subtracted from Error for the covariate.

Appendix D

F-ratios from Analyses of Variance of Arcsine

Percentage Intertrial Responding in

Acquisition and Extinction

SV	df	Acquisition	Extinction
Reinforcement Schedule (R)	2	.09	.38
Sex (S)	1	3.06	7.01*
R X S	2	2.07	1.31
Error $(MS)_a$	65	(78.65)	(80.49)

* p .05

a-One df was subtracted from Error for estimation of a missing data point from the blink rate scores.

Appendix Ea

Percentage CRs and Intertrial Responses (BR)

for Subjects in Group 50-50

S	Males				Females			
	Acquisition		Extinction		Acquisition		Extinction	
	CRs	BR	CRs	BR	CRs	BR	CRs	BR
1.	75.0	57.5	75.0	51.5	42.5	5.7	15.0	1.9
2.	65.0	25.6	50.0	9.7	55.0	13.6	10.0	17.7
3.	95.0	12.0	95.0	7.3	63.8	37.1	20.0	33.7
4.	70.0	10.0	55.0	5.2	21.2	12.5	10.0	8.0
5.	68.8	10.6	40.0	2.7	36.2	10.2	30.0	11.1
6.	47.5	19.4	30.0	12.5	46.2	35.5	100.0	28.1
7.	58.8	16.9	65.0	12.4	78.8	19.5	65.0	20.4
8.	63.8	24.0	25.0	19.2	33.8	12.3	30.0	9.0
9.	77.5	12.2	50.0	14.4	75.0	21.2	85.0	29.0
10.	15.0	20.6	15.0	14.3	21.2	8.5	10.0	8.9
11.	8.8	8.5	15.0	11.5	76.2	26.5	95.0	23.5
12.	48.8	29.2	25.0	20.9	51.2	23.0	25.0	13.3

Appendix Eb

Percentage CRs and Intertrial Responses (BR)

for Subjects in Group 50-100

S	Males				Females			
	Acquisition		Extinction		Acquisition		Extinction	
	CRs	BR	CRs	BR	CRs	BR	CRs	BR
1.	91.2	44.7	15.0	4.2	45.0	18.7	25.0	12.1
2.	71.2	11.3	70.0	6.2	26.2	22.5	10.0	17.1
3.	47.5	15.2	30.0	9.8	46.2	25.3	15.0	22.9
4.	27.5	3.8	15.0	1.7	66.2	10.8	80.0	15.4
5.	35.0	19.4	50.0	17.6	57.5	17.3	20.0	11.9
6.	43.8	16.4	10.0	17.9	37.5	10.8	20.0	5.7
7.	60.0	28.6	50.0	24.6	68.8	53.2	60.0	47.7
8.	58.8	7.7	20.0	3.7	41.2	3.0	10.0	1.8
9.	78.8	32.2	95.0	30.2	93.8	17.2	45.0	13.4
10.	21.2	3.0	00.0	.9	23.8	24.8	10.0	26.1
11.	20.0	10.7	00.0	5.8	25.0	19.2	30.0	9.9
12.	80.0	16.5	100.0	10.5	7.5	28.1	00.0	15.2

Appendix Ec

Percentage CRs and Intertrial Respnses (BR)

for Subjects in Groups 100-100

S	Males				Females			
	Acquisition		Extinction		Acquisition		Extinction	
	CRs	BR	CRs	BR	CRs	BR	CRs	BR
1.	82.5	6.6	10.0	5.6	86.2	16.0	25.0	9.0
2.	63.8	20.6	40.0	17.1	73.8	21.0	75.0	19.8
3.	67.5	--	20.0	--	48.8	26.7	70.0	24.4
4.	93.8	7.6	10.0	.9	47.5	11.0	00.0	22.0
5.	67.5	8.3	20.0	5.2	33.8	44.2	10.0	15.8
6.	67.5	11.8	10.0	10.1	86.2	55.1	60.0	51.2
7.	83.8	18.1	15.0	2.3	40.0	20.8	5.0	17.1
8.	91.2	30.1	30.0	21.6	63.8	15.3	10.0	6.2
9.	91.2	25.3	35.0	24.7	58.8	57.6	10.0	32.8
10.	80.0	6.4	15.0	4.9	75.0	9.4	25.0	2.2
11.	63.8	5.9	00.0	.3	43.8	35.6	5.0	35.4
12.	33.8	16.1	00.0	9.6	57.5	13.6	30.0	15.8

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Louis E. Price

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